CHAPTER XXVI.

ROLLS FOR THREE-HIGH MILLS.

General Considerations.—In a three-high as in a two-high mill each roll is usually slightly larger in diameter than the one below it. In a set of three-high cogging rolls, with box passes, the diameter of the rolls at the bottom of any groove increases slightly from the lower roll upwards, and if only a moderate reduction of a heavy section is needed, the collars on each roll may project about an equal distance from the body, so that they meet at about the middle of the section of the piece being rolled, as in fig. 389; but

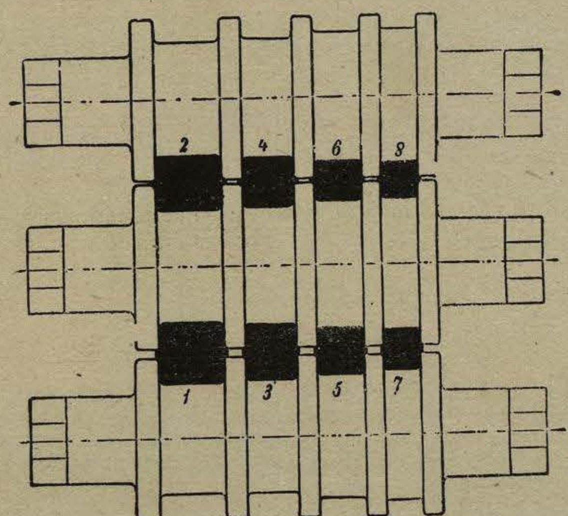


Fig. 389.—Three-high Cogging Rolls.

with heavy draughts a fin would be formed by the metal squeezing out between the collars in the lower pass, and as the space between the collars of the succeeding upper pass would coincide with the same portion of the bar, the fin would increase so much in the upper pass that it would spoil the billet; to prevent this the collars on the middle roll usually project beyond the bottom of the groove only about half as far as those on the top and bottom roll, so that the gap between the collars occurs at about one-third of the distance from the top of the piece in the lower, and one-third from the bottom in the upper part, by which means any fin formed in one pass is pressed flat in the succeeding pass, and not intensified as it would be in the first arrangement. The rolls (fig. 390), it will be seen, are designed on this plan, and in each case the passes are numbered in the order in which the piece passes through them.

If the collars are so arranged that the fins formed in one pass are pressed down in the succeeding one, material requiring reduction in thickness only can be rolled, the whole time with the same side upwards, provided allowance has been made in the width of each pass to accommodate the lateral spreading

which has necessarily taken place in the previous pass. Tin plate bar and other flats are often finished in this way. But if width as well as thickness has to be reduced, the piece must be squeezed in both directions, and this necessitates turning the bar on edge. Accordingly the piece, after passing once each way through the mill with the same side up, is turned on edge and passed through the mill once more each way with a fresh side up, and so on until finished. It will be noticed that the *width* of each set of grooves is slightly more than the *thickness* to which the bar had been reduced in the *previous* pass, otherwise the bar would not enter the pass.

Smaller roughing rolls, with Gothic passes for a three-high mill, may be made in a similar manner, the width of the grooves which are in the same vertical plane being alike in all three rolls, but the depth in the bottom roll being greater and in the top roll less than in the middle roll, so that the billet leaves the rolls flatter on one side than on the other. All the above-mentioned being open passes there is no appreciable tendency of the piece being rolled to wedge itself more into one roll than into the other, and there is, therefore, no great trouble in getting the section to leave the rolls freely. Every pass

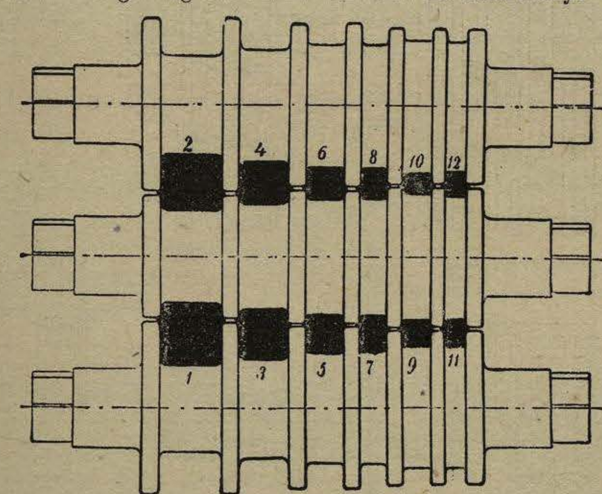


Fig. 390.—Three-high Billet Rolls.

formed by the grooves in every adjacent pair of rolls can be used, because, though the depth of the grooves is different, the form of the top and bottom of the bar is alike, or in the case of the Gothic or diamond passes, the slight difference between the top and bottom of the bar is immaterial. The rolls in the first stand, reckoning from the left hand, in fig. 479, are constructed in this way, the depth of the grooves in each being different.

When sections are needed which necessitate not only the depth, but also the form of the groove varying at every pass, as is usually the case with all sections except flats, the grooves in the middle roll cannot be used for two different passes, and a separate groove in the middle roll must be provided to match the top and bottom roll alternately, the passes which are missed being known as "false passes" (see fig. 392).

When the grooves in the middle roll can be used twice, one stand of three-high rolls will contain as many passes as two stands in a two-high mill, but where every alternate pass only can be employed, the three rolls of a three-high will contain only as many passes as the pair of rolls in the older form of mill, the third roll being the price paid for doubling the speed of rolling.

Closed passes consist of two collars with their "former" between them, and if the passes are to run in regular sequence from one end of the stand to the other, length must be provided on the barrel of the rolls equal to the width of each section, and the collars on each side of it for every pass needed, one collar not serving to separate two adjacent grooves, as in a two-high mill. This arrangement is shown in fig. 391, A. But by splitting the middle roll up into two parts, and pairing one end with the top roll and the other with the bottom roll, one collar can be made to serve for two adjacent passes, as in fig. 391, B, with a considerable saving in the length of the bodies of the rolls; or the centre roll may be replaced by two distinct and separate rolls, each mounted between its own pair of housings, as in fig. 391, C, the centre rolls being coupled up in one continuous line, and having a roll situated above and below the centre alternately. The position of the usual lower or upper rolls in that case is taken by a dummy, consisting of a spindle running in chocks in the housings, just as a roll would do, and provided with coupling boxes and short connecting spindles, as shown in the second and third stands in

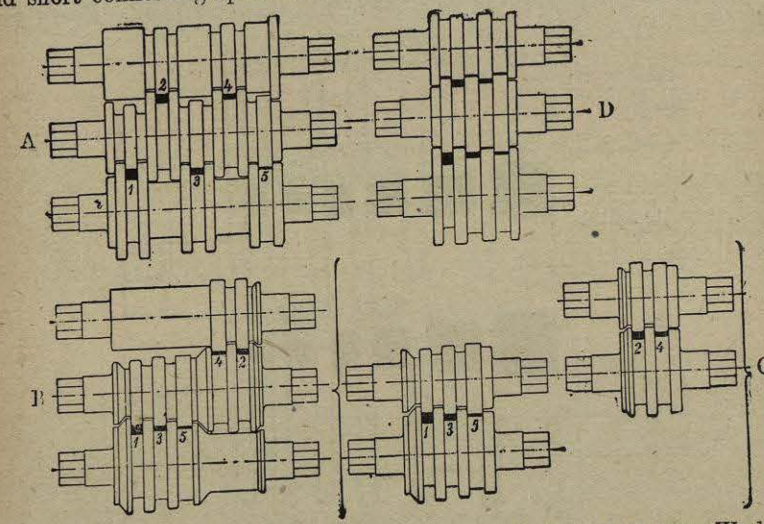


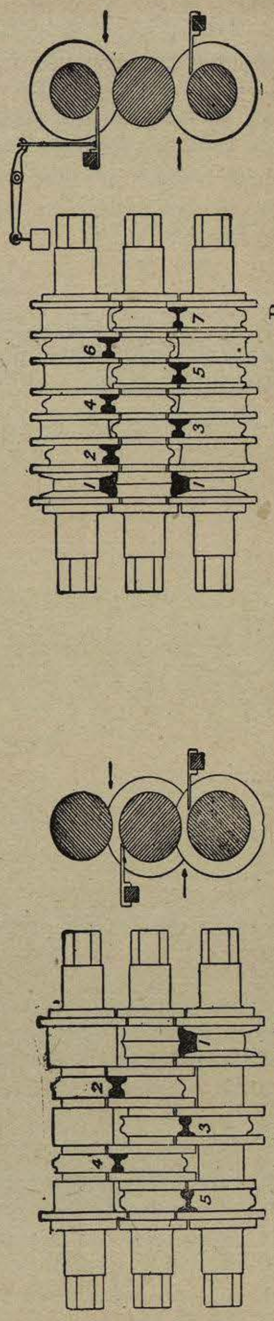
Fig. 391.—Four Methods of Arranging Three-high Rolls to do the same Work.

fig. 501. In some instances, the place of the dummy spindle and its two short coupling spindles, is taken by one long spindle, made of wrought iron for the sake of lightness, as in the fourth stand in fig. 501. In this case bearings in the housings, for supporting the spindles, are dispensed with.

These arrangements entail the disadvantage that the piece being rolled must be moved laterally from one stand of rolls to the other at every pass, rendering its employment impracticable for heavy bars; but for finishing light sections, which are easily handled, this inconvenience is of little consequence, and as it reduces the length of the rolls, it enables heavy draughts to be used without fear of breaking the rolls, which are much stronger when short in comparison to their diameter. On this account the arrangement is much used for mills intended to finish small sections, which cool so rapidly that it is a matter of importance to reduce the section to the greatest extent possible in each pass, thus employing the fewest possible passes, and allowing the material as little time as possible for cooling.

By using the collars on the middle roll to serve alternately as side collars for one pass and closing collars for the next, each pass *can* be made (except

for the two end collars) to occupy a space on the body of the roll equal only to the width of each pass, as shown in fig. 391, D. This arrangement, however, has the disadvantage that it necessitates a greater difference between the diameters of the rolls above and below the bar than is needed to enable the bar to clear properly, the increased scraping of the surface of the upper of the two rolls tending to tear the bar apart and consuming power uselessly in the operation. It further necessitates the axis of the middle roll not being midway between those of the top and bottom roll, throwing the rolls out of line with the pinions which drive them, thus adding to the wear of the wobblers and the risk of breakages. For this reason it is little used, and indeed is only applicable to rolling flats or strips, which are thin in comparison to the diameter of the rolls employed to form them.



B American Three-high Rail Mill.

Fig. 392.

A English Three-high Rail Mill.

The American Three-High Mill.—Fig. 392, A, shows a set of rolls for use in a three-high rail mill, according to common English practice, in which the bottom and middle rolls are grooved to receive the rail, while the "closers" are on the middle and top rolls, and the guards to peel the bars out of the grooves rest by gravity on the bottom and middle rolls, one on one side of the mill and one on the other, the middle roll acting alternately the part of a top and of a bottom roll in an ordinary two-high mill. In the American three-high mill (fig. 392, B) the top and bottom rolls are grooved, and the middle roll serves as the "closer" for each of the others, itself carrying no grooves at all; to enable the bars to be got out of the top groove, the upper guard must be placed on the upper side of the bar as it issues from the roll, and as it will not lie there by gravity, the guard has to be kept up to the roll by a counterweight or spring, and is known as a balanced guard. These are clearly shown in fig. 392, B. It will be noticed that by this arrangement each pass only needs to have the space for one collar allowed on the length of the barrel, and consequently seven passes may be got into the same length of barrel in the American system as will only accommodate five passes by the English plan.

In the latter arrangement the rail has to be turned over at every pass, the head of the rail lying to the right and left hand alternately, so that the fin formed in one pass may be rolled down in the next, but in the American mill the rolling may be continued with the same side up the whole time, as the passes open upwards and downwards alternately, thus, of course, economising labour in rolling.

The inverted guard is looked upon with suspicion by English rollers and mill managers, who comparatively rarely use it, but it is generally employed in America on all mills which do not make more than 150 revolutions per minute; for mills running above that speed it is not considered safe.

With hanging guards the top and bottom rolls are the same diameter, the middle roll being larger than the other two.

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CHAPTER XXVII.

SPECIAL MILLS.

The Dowlais or "Double Duo" Mill.—When a piece being rolled has to make more passes than can be contained in one pair of rolls, the mill devised by Mr. Menelaus, of Dowlais, about 1867, will, if run at the same speed, finish bars as fast as a three-high mill, will occupy less space, and require fewer rolls.

The mill was designed to roll iron girders (known also as "beams" or "joists") which had to be rolled rapidly so as to be finished while still at a good heat. If rolled at as low a heat as that at which steel girders are usually finished, the layers of iron would open up and separate one from the other.

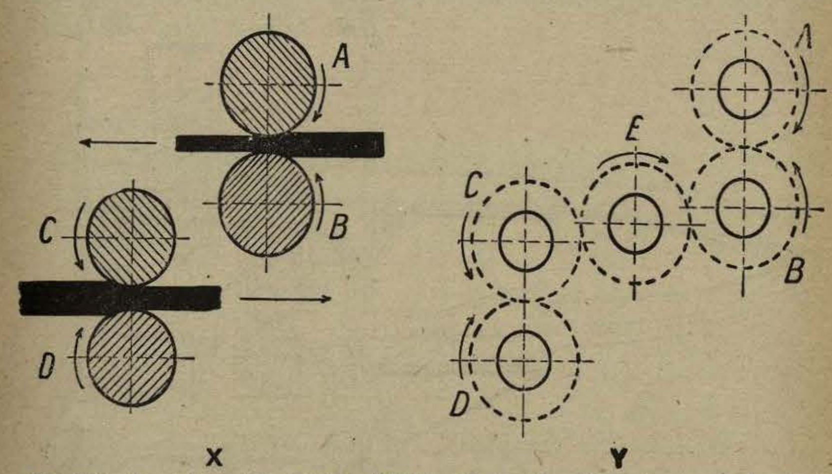

Fig. 393.—Dowlais or "Double Duo" Mill. X, showing the arrangement of rolls; Y, showing the arrangement of pinions.

A 21-inch mill of this kind worked for many years at Dowlais running at over 100 revolutions per minute; it turned out iron girders from 8 to 12 inches deep at a speed of 600 feet per minute, which was a remarkable performance in those days. For work of this kind the mill has now been superseded by the reversing mill, which saves lifting the piece at the rolls, and enables long lengths to be rolled at such a high speed during the middle of their run through the rolls, that their mean speed of travel may be high. For quickly rolling the short lengths, in which all material was finished years ago, it is doubtful if anything could compete with the Dowlais mill.

In this mill there are two middle rolls, B C (fig. 393, X), placed side by side, but not at the same level, the roll, B, which pairs with the top roll, A, being situated so much higher than C, which pairs with the bottom roll, D, that bars can pass between A and B without touching C, and between C and D without touching B. The four rolls are mounted in one pair of housings and run in the direction indicated by the arrows; the bar enters from the left between C and D, and returns between A and B, between which it is rolled on its return journey, exactly as in a three-high mill. There are no false passes, such as are inevitable in three-high mills rolling sections, so that the four rolls in this one pair of housings contain as many available passes as do six rolls of a three-high mill, which must be carried in two pairs of housings, necessitating the transfer of the bar from the first to the second stand before the rolling can be completed.

This design, after being neglected for many years, has recently been adopted in several Continental works, under the name of the "double duo mill," for finishing small rods and strip in long lengths. The cut, fig. 394, is from a working drawing of a stand of such rolls recently constructed, and fig. 502 in Chapter xxxv. shows a complete mill of this type.

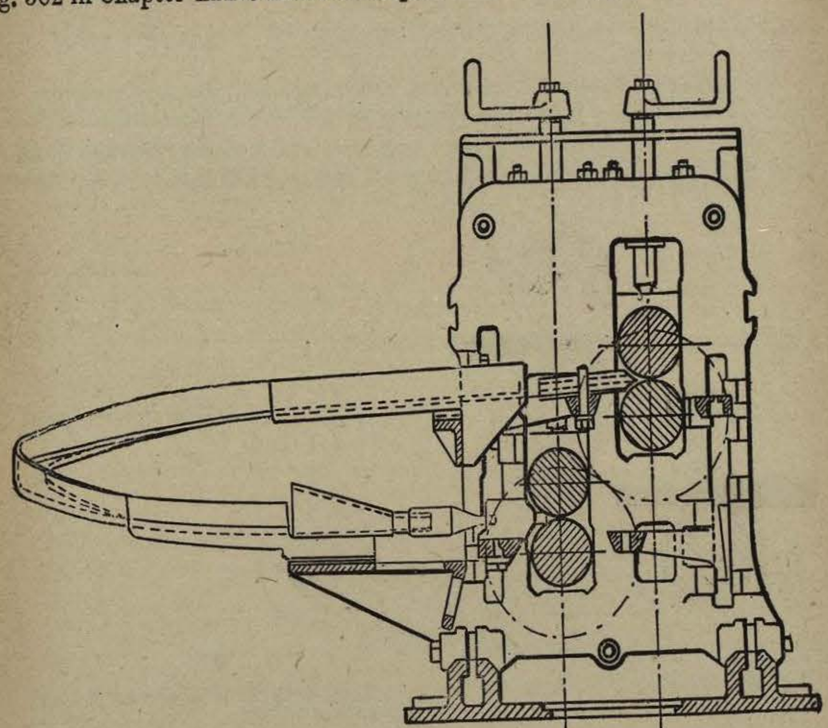

Fig. 394.—Section through the Rolls of a "Double Duo" Mill, with Repeater fixed in position.

There does not appear to be any valid reason why large mills should not be constructed on this principle, instead of on the three-high plan. In some cases—for instance, for rolling girders, for which the mill was originally designed—one stand of such rolls would provide as many passes as two stands of three high rolls, with considerable saving in rolls, and probably in power while the transfer from one lifting table to another would be avoided.

Originally two stands of pinion housings were used. In the stand next the engine were two large pinions, the axes of which were in line with the axes of rolls D and B, providing for the driving of the bottom roll of each pair. In the second stand were two pairs of smaller pinions, whose axes were in line with the axes of the rolls, thus ensuring that the upper roll of each pair worked in unison with its lower fellow. It is usual now to employ the more compact arrangement of five pinions, all of one size, in one stand,

as shown in outline in fig. 393, Y. The crank-shaft of the engine is coupled to the middle pinion E, which gears into pinions C and B, and these in turn into A and D respectively.

Brown's Mill, sometimes called the reciprocal mill, also had four rolls arranged in one pair of housings, and consisted of two pairs of two-high rolls placed close together as in fig. 395. The two pairs of rolls were driven in opposite directions, but every alternate pass in one pair of rolls was made so much larger than the corresponding pass in the pair beyond, that the bar passed freely through the enlarged pass of the near pair into the grooves in the second pair, where it was reduced in the ordinary way. In fig. 395, *a* shows the forward and *b* the return pass between the same pair of rolls.

The arrangement of the driving pinions is seen on the right of fig. 395. Each of the lower pinions has two sets of teeth, those on one face being on a larger circle than those on the other cast with it. The driving shaft is coupled to the larger end of one pinion, *d*, the teeth on which gear into similar teeth on circle *c* on the other bottom pinion. The teeth on the smaller circles, *e* and *g*, gear into teeth, *f* or *h*, on the pinion above, each top pinion having only one set of teeth.

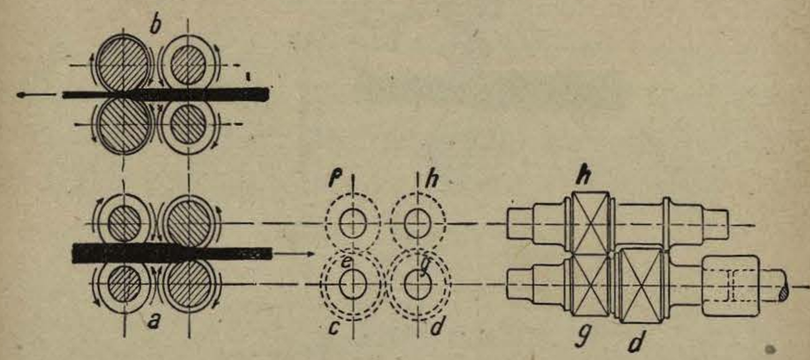

Fig. 395.—Brown's Reciprocating Mill. Arrangement of Pinions is shown on right side.

It will be noticed that the bar does not enter the operative pair of rolls, until after it has passed between the inoperative pair running in the contrary direction. The rolls are thus kept close together in one pair of housings, with the guards on the outer sides front and back. Were the arrangement reversed, a displaced guard, or a bar with a split end, which is generally opened out by rolling into the form of the letter Y, or one which for any reason did not leave the rolls straight would be carried into the mill, where it would cause much damage to the machinery, and probably injure the men also.

As the passes were enlarged in each pair of rolls alternately, the engine and rolls could be kept running continuously in one direction, and yet the bar could be worked both going and coming without having to be lifted from the floor. This advantage, however, is purchased at the expense of having to provide and keep in continual motion twice as many rolls as are needed for a reversing mill, and one-third more than are required for a three-high mill. This has prevented any great number of such mills from being constructed, and not many are now left at work.

Lauth's Mill.—As previously explained, small rolls will draw out a piece rolled between them more rapidly than large rolls, and with the expenditure of less power; but *when both pairs are of equal length in the barrel*, it is obvious that the smaller will break with much less load than the larger ones, and cannot, therefore, be safely screwed down to give the same pressure on a plate passing through them. Plate mill rolls, therefore, must be made of considerable diameter if they are to be sufficiently strong to roll plates of any width with reasonable rapidity and freedom from accidents.

Mr. B. C. Lauth, of Pittsburg, seeing that the smaller roll would do the work more rapidly, if it only had sufficient strength to withstand the pressure, devised the arrangement shown in fig. 396. In this mill a roll of small diameter is used to notch down the plate, this small roll being supported throughout its entire length by a roll of larger diameter. The small centre roll is generally about two-thirds the diameter of the top and bottom roll, which serve alternately to support it against the bending stresses set up in it by the plate being rolled, and as the strength of the body of two rolls of similar length subjected to transverse load varies directly as the cube of their

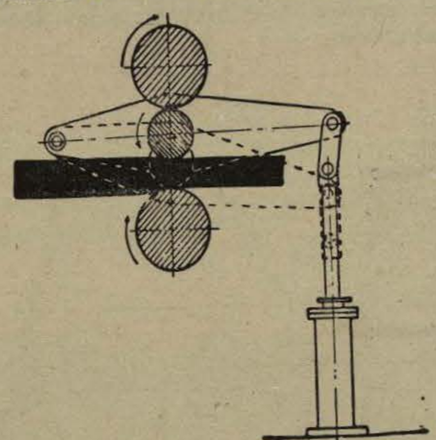

Fig. 396.—Lauth's Mill.

respective diameters, the strength of each large roll is about $3\frac{3}{8}$ times that of the unsupported small roll. Three housing pinions are employed as in an ordinary three-high mill, the engine being coupled to the middle pinion, which is usually smaller than the top and bottom ones, and the top and bottom roll to the top and bottom pinion; the middle roll, however, is not driven, but runs free in chocks which can play up and down in the housings. When a plate is to be passed below the centre roll the chocks carrying it are raised by two hydraulic or steam cylinders, and the piece passes between it and the bottom roll; when it is to be returned the middle roll is allowed to fall on to the bottom roll, and the plate passes back between the middle and the top rolls. The top roll is balanced in the manner customary with all plate mills, and is screwed down to regulate the thickness in the usual way after every pass. The drawing shows the method originally employed for raising and lowering the centre roll. In the most recent mills it is performed by admitting and removing water from cylinders placed below the housings, similar generally to the balance cylinder shown in fig. 350.

Nearly all the American plate mills (see fig. 493) and a few on the Continent are constructed on this system, but it has never met with favour in this country, where the reversing mill is preferred.

The Universal Mill.—Flat bars generally are rolled in grooves which are cut in the lower roll and closed in by the former on the upper roll. The width of the bar is determined by the width of the groove, and its thickness may be varied by the extent to which the upper roll is screwed down. The cost of preparing special rolls, for every trifling difference in the width of bar, is considerable, and to get over this difficulty the universal mill was constructed by Mr. Daelen at Hoerde about 1855. One was exhibited at the Paris Exhibition of 1867, at which time there were a good many in use on the Continent. The mill, although having a German origin, is often called the Belgian mill; it is chiefly used for producing what may be designated either wide flats or narrow plates, and is used in America for plate-rolling, but has never met with much favour in this country, where flats up to 18 inches wide are rolled in grooved rolls.

The universal mill consists of a pair of ordinary plain cylindrical rolls mounted in the usual way, and at the back of these a shorter pair of similar rolls mounted with their axes vertical, so as to compress the bar edgeways at the same time as the horizontal rolls compress it on the flat (see fig. 397).

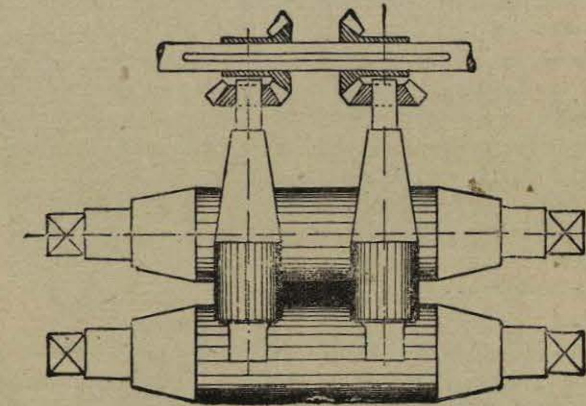

Fig. 397.—The Universal Mill.

The vertical rolls, which are usually somewhat smaller in diameter than the horizontal rolls, are generally driven from their upper ends by means of mitre wheels, gearing into other mitres keyed on a shaft crossing the top of the housings, on the end of which shaft is a spur-wheel, gearing into the upper pinion in the pinion housings, or with a spur-wheel keyed on it. Originally the vertical rolls were driven from their bottom ends, but so much damage was done by scale falling on to the gearing that now they are all driven from the top. It will be seen that by this combination of four rolls any width and thickness of flat bar, within the compass of the mill, can be rolled with equal facility.

If the piece to be rolled is not entered perfectly square, or if it bears much harder on one vertical roll than on the other, it will be curved in the horizontal direction, and the same thing occurs if the piece is not evenly heated, the hotter side extending more than the colder, and once bent it is not easy to straighten it. As a piece being rolled increases in length it must leave the rolls at a higher speed than it enters them, the precise difference between the speed of travel at front and back depending upon the amount of reduction effected in the pass. The speed of the surface of the vertical rolls at the back must, therefore, be greater than that of the horizontal rolls through which the bar has just passed, by an amount depending entirely upon the extent to which the top roll is screwed down at each pass. Any deficiency in the surface speed of the vertical rolls would prevent them from passing on the bar as fast as they received it, and it would then, if thin, accumulate in a crumpled mass between the pairs of rolls, and be spoiled. To avoid this, the vertical rolls must always be run somewhat faster than is required theoretically. As it is impossible to guard against a workman putting on too much draught at a pass, this speed must in practice be very appreciably in excess of the correct amount. This involves much slipping of the edges of the bar on the surface of the vertical rolls, whereby they are rapidly worn out, absorbing much power uselessly and causing considerable "back lash," which is very destructive to the gearing. Even if the surface speed of the two sets of rolls is correctly proportioned when the rolls are new, the relation is destroyed as they are turned down to correct for wear.

In some mills these defects are partially corrected by placing, somewhere in the shaft driving the vertical rolls, some kind of friction clutch, thus transferring most of the slipping from the rolls to the clutch faces, where it does less harm. In others the vertical rolls are driven by clutches with teeth which are square on the driving face, but inclined on the other, with the object of keeping the rolls in motion, and yet permitting them to run with the plate leaving the mill, should it travel so fast as to overrun the speed at which the gearing would naturally drive the rolls. One mill at the Bethlehem Works has the horizontal rolls, driven by one pair of reversing engines and the vertical rolls by a second pair of similar engines of less power. Fig. 398 shows a 40-inch reversing mill, as made for the National Tube Company, of M'Keesport, Pa, by the Mesta Machinery Company, of Pittsburg, to reduce 56-inch × 30-inch ingots to slabs of any reasonable size down to 14 inches wide. The steel horizontal rolls are 32 inches diameter by 65 inches long in the barrels. The housings weigh about 50 tons each, and the rolls are driven by a pair of 46-inch × 60-inch reversing engines, geared to the mill with cast-steel wheels, in the ratio of 5 to 7. The vertical rolls are of steel, 22 inches diameter, and are driven by a pair of 36-inch × 48-inch engines. The vertical housing weigh about 70 tons each, and the gearing is all steel.

To enable the vertical rolls to be driven by mitre wheels of 52 inches diameter, and yet be able to deal with slabs down to 14 inches wide, without having to resort to the use of idle rolls between the driven rolls and the slab, the mitre wheels are placed at different heights, so that they overlap, and are each driven by an independent shaft.

Both three-high and reversing universal mills have been used, with vertical rolls on either and on both sides of the horizontal rolls.

The universal mill is not an easy one to work, much skill being needed on the part of the man who adjusts the rolls, and it is consequently not in favour with mill managers in this country, who prefer to roll wide flats of 18 and even 24 inches wide in ordinary grooved rolls. They argue, with some show of reason, that heavier draughts can be taken in this way, so that the time saved in rolling more than makes up for any saved in changing rolls, and say they would rather keep more rolls in stock, than more machinery in repair. Further, a piece cut across the end of a wide bar does not give as satisfactory a test as one cut from the end of a plate, and until the Westminster Engineers relax their requirements in this respect, the owner of a large universal plate mill would find it difficult to dispose of its product in this country.

On the Continent, where orders are received in quantities too small to justify the cutting of special rolls, the mill is used extensively. There are

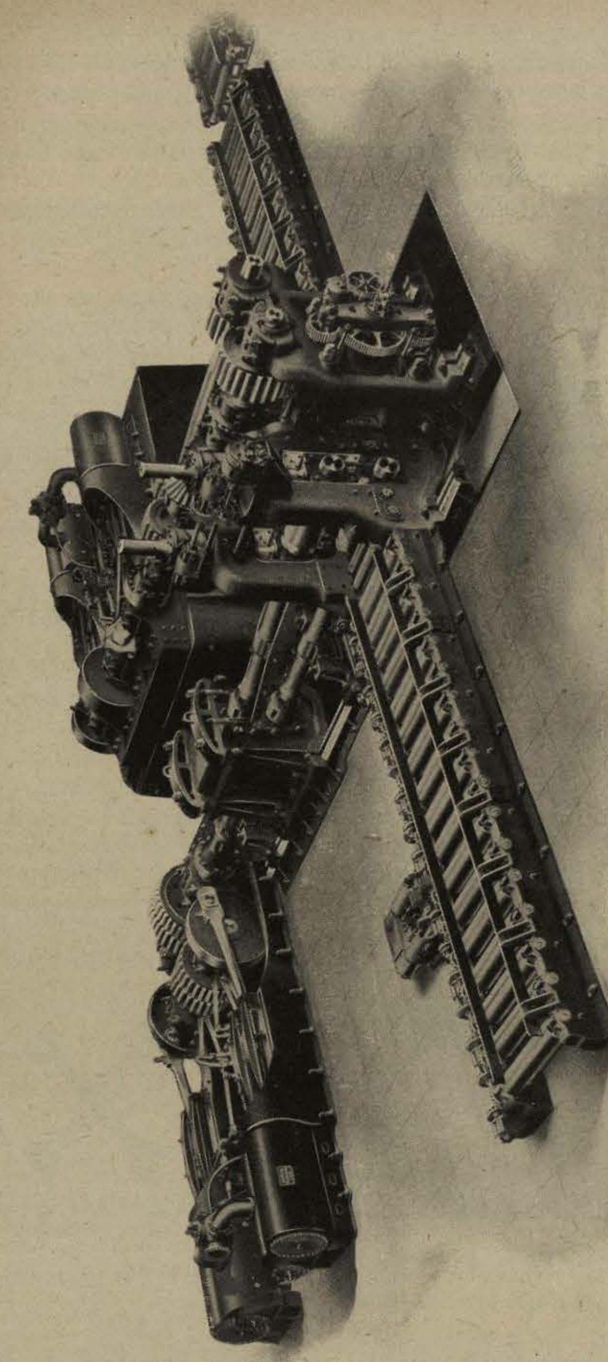

Fig. 398.—Universal Slabbing Mill and Engine. Each pair of rolls driven by its own engines.

said to be between 40 and 50 in the German Empire A 26-inch three-high universal mill, in a Continental works, with a pair of vertical rolls on the back of the mill, is turning out "gas strip" up to 18 inches wide, to be bent up and welded into tubes, at the rate of 50 to 60 tons per twelve-hour shift, using well heated ingots of 1 ton weight each, the strip being beautifully straight, and the edges quite sharp and true. In America, where tests are not so stringent, plates up to 3 feet 6 inches wide are generally rolled in this type of mill, and from the largest a production of 250 tons is obtained per shift of twelve hours. The plates from universal mills usually have their edges straightened by pressing them while lying hot on the floor, between two bars which are squeezed against the plates laterally.

Wenstrom's Mill, which was invented by Mr. W. Wenstrom, of Orebro, Sweden, about 1880, is a development of the universal system, but instead of acting on the flat and edge of the bar alternately, it compresses all four surfaces simultaneously, the axes of all four rolls being situated in the same vertical plane. Fig. 399 shows the arrangement of this mill. The roll, *A*, can be adjusted vertically, and the roll, *B*, which always remains on the same level, is adjusted horizontally; the vertical roll, *C*, remains always in the same position, touching both rolls, *A* and *B*, while the other vertical roll, *D*, is carried in a frame which follows *A* in its vertical adjustment, but at the same time can be moved laterally to follow the end on movement of roll, *B*. As the vertical rolls, *C*, *D*, never grip the bar alone, there is no necessity to drive them, and they consequently run free, the rolls, *A*, *B*, only being driven by means of the spur-wheels, *E*, *F*. Several of these mills are in use in Sweden, where they appear to give satisfaction in the rolling of thin bars.

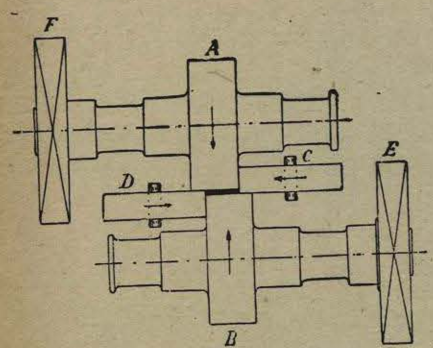

Fig. 399.—Wenstrom's Mill.

Sack's Mill, patented about 1885 by Mr. Hugo Sack, of Duisburg, is

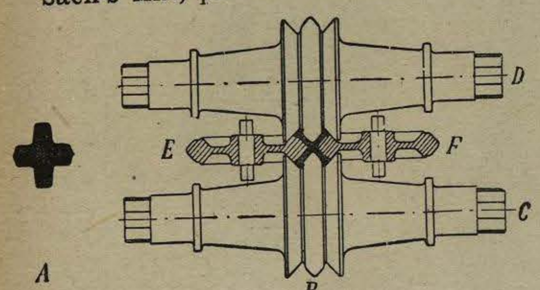

Fig. 400.—Sack's Mill.


Fig. 401.—Section Rolled in Sack's Mill.

intended for rolling cruciform sections, such as the one shown in fig. 401. The bloom is cogged down to about the section, *A* (fig. 400), in an ordinary mill, and finished to the section (fig. 401) in the Sack's mill. The roll, *C*, is fixed, while *D* is adjustable vertically, and *E* and *F* horizontally, all three adjustments being effected simultaneously from one shaft.

Grey's Mill is a special form of universal mill, intended to produce from one set of rolls, girders which vary in the thickness of the web and in the

thickness and width of the flanges, the intention being to avoid the expense of cutting fresh rolls to suit variations in the dimensions of rolled joists. Two stands of rolls are used, one placed directly in front of the other, so that the girder travels through both stands of rolls at every pass, as in a continuous mill. Each housing also carries a pair of vertical rolls between the necks of the horizontal rolls, the axes of all four rolls in a housing being situated in one vertical plane, as in the two previous mills. In the first stand (fig. 402), the web of the girder is pressed between the horizontal rolls, *A*, *B*, which determine its thickness, and the flanges between the ends of the rolls, *A*, *B*, and the faces of the vertical rolls, *C*, *D*, which determine their thickness, but leave them free to spread to any width, this width being determined by the rolls,

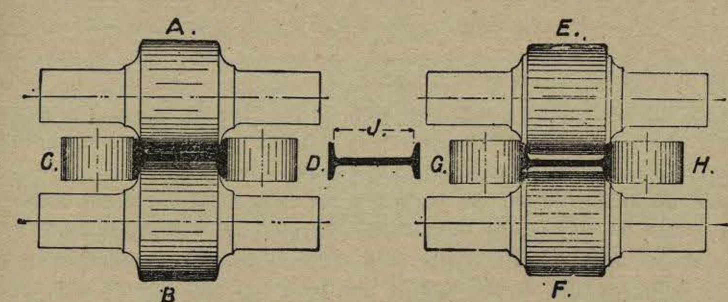

Fig. 402.—Grey's Mill.

E, *F*, in the second stand, which do not touch the web, but act only on the edges of the flanges, which are held in position, and prevented from thickening or turning over by the rolls, *G*, *H*. Thus the only dimension which is invariable is the distance, *J*. The width of flange, its thickness, and the thickness of the web are all variable at will, within considerable limits.

This mill can turn out girders with flanges wider and thinner than any which it is practicable to make in rolls of the usual construction.

The arrangements of the guides, the methods of driving the vertical rolls, and for securing simultaneous adjustment, are exceedingly ingenious and complicated, but would require more space to illustrate and describe than can be spared in the present work. This and Sack's mill are in use on the Continent, yet neither have so far been adopted to any great extent; but girders rolled in the latter are now obtainable up to 29½ inches deep by 12 inches wide on the flanges, while those rolled in the ordinary way do not exceed 8 inches wide. The proprietors of the mill contemplate eventually rolling girders as much as 36 inches deep by 12 inches wide.

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